Effect of Spacing on Legend Interpretation of Maps

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Abstract. Legend design is an indispensable component in designing maps. Effective design makes visual search in a legend more efficient and accurate. A usability-based survey for evaluating some current legends indicates that some legends are more effective than the others. It has been found that one of the differences among those legends is spacing. There are many types of spacing within a legend (e.g. spacing between a symbol and its description). Thus, our purpose is to investigate the effect of spacing on legend interpretation of maps for effective legend design. To do so, visual search and time expenditure in a legend is effectively recorded by using human-computer interaction for analysing the accuracy and efficiency. An experimental evaluation of different legends designed with different combination of spacing has been implemented in form of Web-based test and results indicate that to make a legend more effective, all types of spacing within a legend must follow a hierarchy (from large to small): surrounding spacing of groups (columns/rows) of items, spacing between adjacent feature items, spacing between a symbol and its description, spacing between words in a description, and spacing between letters of a word.

Keywords: legend, spacing, human-computer interaction, effective design

1. Introduction

A legend is one of important components for most maps, as it assists readers to understand maps. Therefore, legend design is an important topic in cartography. To make a legend more effective is one of basic objectives in legend design. An effective legend means accurate and efficient visual search for legend items to interpret map symbols.

Design an effective legend includes the design of different legend components, which are a panel, a title, and items (symbols and descriptions). A legend is normally in vertical form with columns of items (Bohme, 1984). A usability-based survey of some ordinary legends (see *Figure 1*) developed by us indicates that some legends are more effective than the others.

(a) legend of Catharine Valley Trail (Nysparks, 2011)

(b) legend of South Africa Tourist Map (Mappery, 2011)

(c) legend of Hong Kong MTR System Map (MTR Corporation, 2010)

Figure 1. Ordinary legends evaluated.

Through carefully examining the above legends, it has been found that in legend design the spacing among adjacent legend items and among their components (graphic symbols and letters) is different among the legends. Dose it influence the effectiveness of legends? Based on this question, the effect of spacing on legend interpretation of maps was investigated in this research.

Since 1980s, some studies on effective legend design have been carried out. For example, a study by Delucia (1982) indicates that, if feature symbols are seen in a visual context more closely resembling their actual situations within the body of the map, the efficiency of map interpretation may be significantly improved. Evaluations of legends for specific types of maps were conducted, such as soil maps (Ellehoj, 1990) and unclassed bivariate choropleth maps (Aspaas, 1989). Buziek (2000) suggested effective design of legends for non-interactive cartographic animation, such as highlighting by moving spotlight (see *Figure 2*). Christophe (2008) developed an interactive way for design and generating effective legends of Web maps.

Figure 2. Hightlighting by moving spotlight (Buziek, 2000).

It can be noted here that most of studies about effective legend design focus on legends of special maps and there are very few studies based on the principles/experimental findings to guide the effective design of ordinary legends.

The remainder of this paper is organized as follows. Section 2 introduces

human-computer interaction for cartography; Section 3 describes evaluation of spacing on legend interpretation of maps by using human-computer interaction; Section 5 demonstrates conclusions of this study.

2. Human-computer interaction for cartography

Generally, a good map is designed by cartographers, who are experienced many training and practises. With following many good cartographic guidelines for best practise published, such as Dent et al. (2008) and Robinson et al. (1995), cartographers are empirically trained. However, such specific parts on cartography, like spacing among elements constituting a legend, are still arbitrarily determined based on cartographic guidelines. For example, cartographers are trained to align and evenly distribute map elements, or make sure of colour/space balance in designing/making maps. There is little standard/regulation to follow.

To fill in this gap, human-computer interaction (HCI) is very useful and important, because it is very effective in testing map reading. When a map is display on screens, the visual search (represented by mouse click, screen touch and any other input forms) during map reading is able to be recorded. With the fast development of computer hardware, such high speed hard disk, RAM memory, CPU and Internet devices, the basic data process/ input/output of a computer is faster than human reaction, which provides the capability of effective test of map reading. Therefore, human computer interaction is the best way to find the most effective legend design.

Morrison and Forrest carried out studies in cartography using human-computer interaction. Their experiments are well done and indicate some findings, which are more strongly supported than some descriptions in cartographic guidelines. They did the experimental evaluation about the size of pictorial symbols on screen based tourist maps based upon statistical data of time spent and correct rate of visual search for symbols by subjects in 1995 (Morrison, 1995). Twelve pictorial symbols (see Figure 3) with three types of sizes (22px2, 18px2, and 14px2) were displayed on the street map of Eastbourne. Experimental findings indicate that symbols with large size (22px2, 8.5mm2) perform better in display than medium size (18px2, 7mm2) symbols, which do better than small size (14px2, 5.5mm2) symbols.

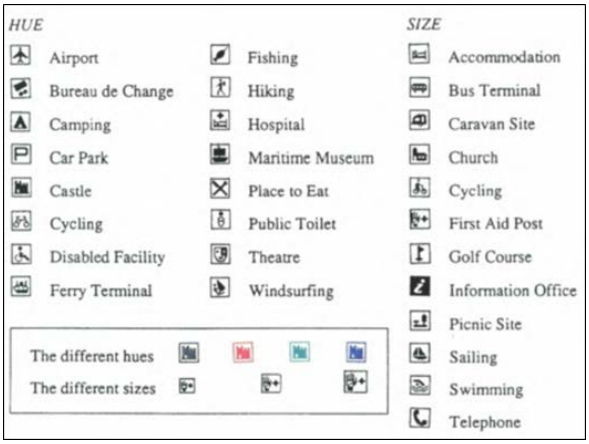


Figure 3. Symbols used for testing toward hue and size (Morrison, 1995).

They also evaluate the colour of symbols. Effect of four different colour of symbols (see *Figure 3*), which are black, red, green and blue, are evaluated in the same way. Experimental results show that the performances of colour of symbols from the best to the worst are black, green, red and then blue, which is not like the expectation described: red is best and blue is worse.

By using human-computer interaction, the effect of spacing can also be effectively evaluated. The experiment is described in the next section.

3. Evaluation of spacing for effective legend design

3.1. Experimental design

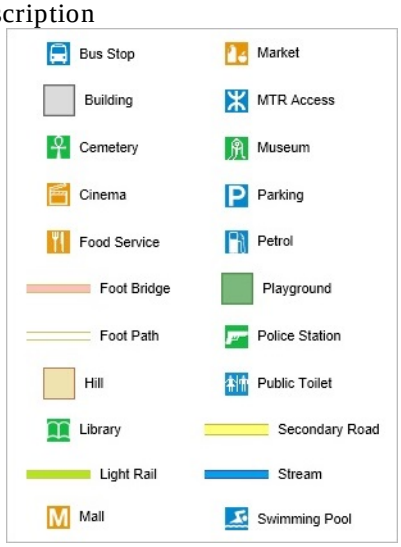
This experiment aims to evaluate the effect of spacing on legend interpretation of maps. An experimental evaluation was conducted in the form of Web-based test, which is in between-subjects design (different groups of people testing different legends) to avoid experiences effect. Through testing a set of legends, which are designed by applying different combination of spacing, the effect of spacing on legend interpretation is able to be investigated by measuring the accuracy and efficiency of visual search in the process of human-computer interaction.

The testing legends (see *Figure 4)* designed by considering different combination of spacing are shown as follows.

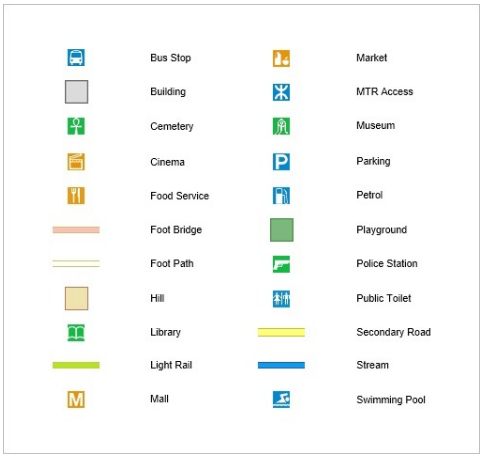
Legend s1: hierarchical spacing*

Legend s2: spacing between letters is larger than spacing between words in a description

Legend s3: spacing between words in a description is larger than spacing between described symbol and the description



Legend s4: spacing between adjacent lines of feature items is larger than spacing surrounding the groups of feature items



Legend s5: spacing between a symbol and its description is larger than spacing between adjacent lines of feature items

Figure 4. Legends (5 sets) designed with consideration of different combination of spacing.

(* from large to small: Surrounding spacing of groups, as feature items in groups (columns); Spacing between adjacent lines, as each feature item is aligned in lines; Spacing between a feature symbol and its description; Spacing between words in a feature description; Spacing between letters in a word)

By making use of human-computer interaction, the experimental results are recorded in high quality in terms of the high efficiency of data process/input/output, not like recording by human reaction. During the interaction, through recording feature item and time expenditure of each visual search on a legend, it is easily to measure the accuracy and efficiency of visual search on a legend.

A system for the test was developed. When a participant is logging, the test instructions are shown. After filling the form (personal information) at the bottom of this page and clicking next button, a map relevant to all tested legends is shown for 3 minutes and then the test is started with the screen show turning to the actual test interface. In the actual test interface, a legend randomly selected from all tested legends is shown at the left side. Right of the legend, a sequence of feature symbols (see *Table 1*) is used for visual search on the legend.

No.	Feature Symbols
1	
2	
3	
4	
5	
6	
7	

Table 1. Feature symbols used for visual search of feature items.

The structure of the system (see *Figure 5*) is illustrated as follows.

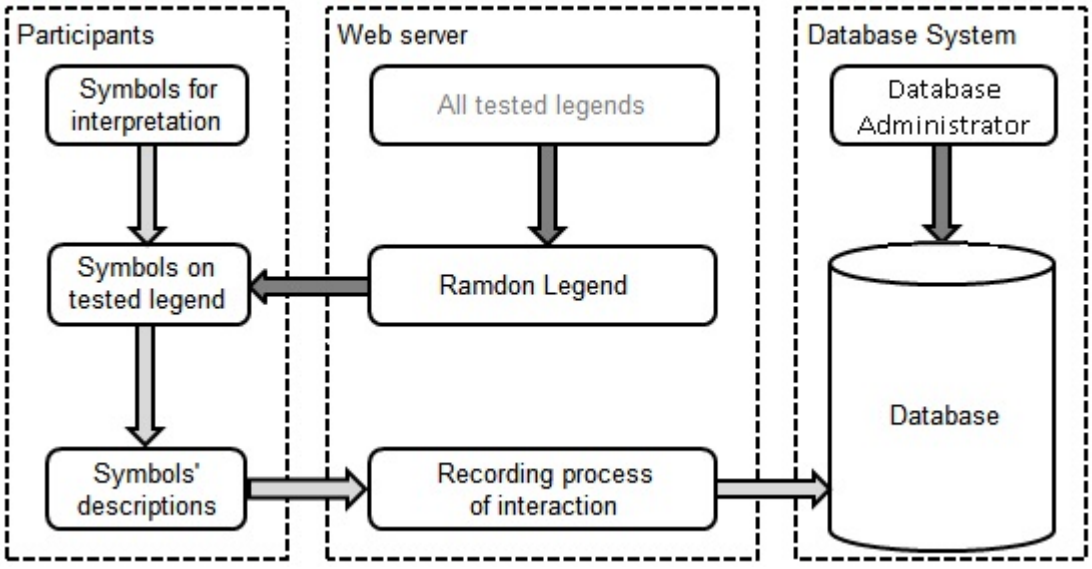


Figure 5. Structure of the test system.

It is a Web-based interactive testing system. Descriptions of feature symbols on each legend are selectable by mouse. Generally, the whole process of interaction (visual search for a feature item) in test can be divided into three sections: visual search, moving mouse, and selection. Each visual search and time expenditure are automatically recorded by the system in every interaction.

3.2. Experimental results

Based on the record of visual search, a statistical analysis is made. As the accuracy of visual search for all legends is very high (almost 100%), only the efficiency is compared among the legends. The cumulative time spent on visual search is presented in *Table 2* below.

Legend: Spacing	Mean Cumulative Time Spent (Sec.) on Visual Search													
	1		2		3		4		5		6		7	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
s1: hierarchical spacing	5.5	0.5	9.2	0.9	12.1	1.2	15.5	1.3	17.1	1.4	20.4	1.6	23.2	1.9
s2: spacing between letters is larger than spacing between words in a description	5.8	0.4	9.6	0.9	12.8	1.1	16.1	1.3	18.5	1.6	21.7	1.8	24.9	2.0
s3: spacing between words in a description is larger than spacing between described symbol and the description	6.1	0.6	9.0	0.8	12.4	1.2	15.7	1.4	18.2	1.7	21.6	2.0	24.9	2.3
s4: spacing between adjacent lines of feature items is larger than spacing surrounding the groups of feature items	6.5	0.3	9.9	0.8	13.7	1.0	17.2	1.3	20.0	1.5	23.3	1.7	26.2	2.0
s5: spacing between a symbol and its description is larger than spacing between adjacent lines of feature items	6.7	0.5	10.5	1.1	14.2	1.3	18.0	1.5	20.8	1.9	24.6	2.4	28.0	2.8

Table 2. Statistical results of mean cumulative time spent on searching for 7 feature items on each of testing legends (M = mean cumulative time spent and SD = Standard Deviation).

The corresponding curve charts (see *Figure 6*) were plotted based on the above statistics. Based on the diagrams, it can be obviously found that Legend s1 is the best; Legend s3 and s2 are better; and Legend s4 and s5 are worse.

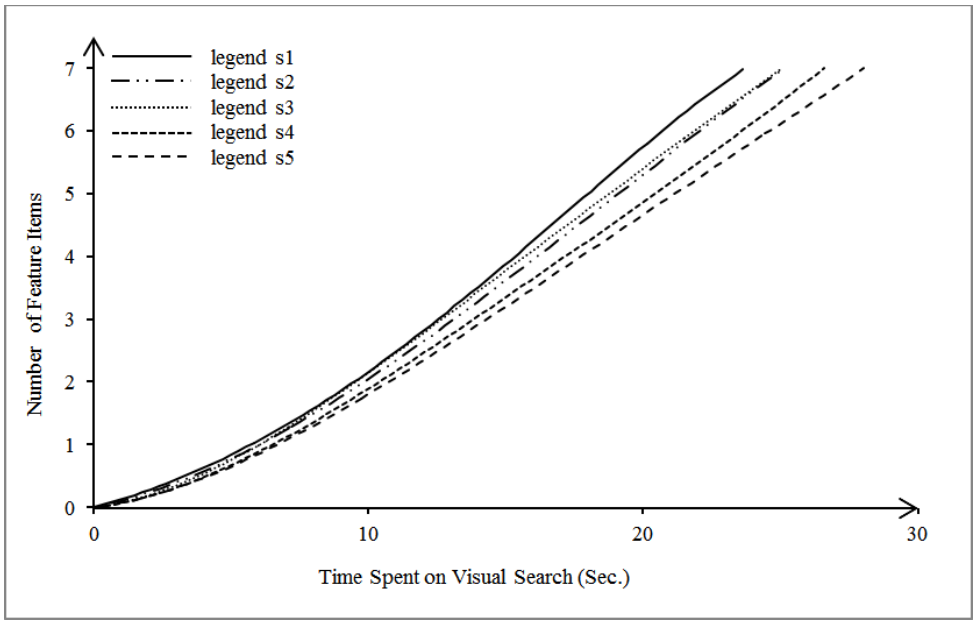


Figure 6. Statistical diagrams of mean cumulative time spent on searching 7 features items in each of legends designed with consideration of different combinations of spacing.

The statistical difference and its significance among the results of 5 legends were tested by using ANOVA (analysis of variance). F-test results (see *Table 3*) indicate that there is at least one statistical difference among the 5 legends within each of 7 cumulate time of visual search.

	1	2	3	4	5	6	7
F	11.86	6.85	7.67	9.80	10.90	10.61	10.56
P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 3. F-test results of 7 types of cumulative time spent on visual search among the 5 legends designed with consideration of different combination of spacing (P means probability of null hypothesis and Fcrit = 2.47 (0.05 significance level)).

For investigating the statistical differences among the 5 legends, the post-hoc analysis was made. The T-test with Bonferroni correction is used for multiple pairwise comparisons in the 5 legends in cumulate time of 4 and 7 times of visual search, because of the obvious differences of efficiency after 4 times of visual search. The T-test results (see *Table 4*) indicate that 4 out of 10 comparisons have significance in statistical difference. Particularly, Legend s5 has the most number of significance comparing with the other legends. Legend s1 is the second.

Legend (4 times)	s1	s2	s3	s4
s2	no			
s3	no	no		
s4	**Yes**	no	no	
s5	**Yes**	**Yes**	**Yes**	no

Legend (7 times)				
s2	no			
s3	no	no		
s4	**Yes**	no	no	
s5	**Yes**	**Yes**	**Yes**	no

Table 4. T-test results of 4 and 7 times of cumulative time spent on visual search between each pair of the 5 legends (Yes means significance in statistical difference).

4. Conclusion

Through an evaluation of such ordinary legends, it has been found that some legends are more effective than the others and one of the significant differences in legend design among the legends is spacing within a legend (e.g. spacing between a symbol and its description). Thus, in this study, the effect of spacing on legend interpretation of maps was investigated. By making use of human-computer interaction, each visual search and time expenditure were effectively recorded in experimental evaluation of spacing. All experimental results indicate that:

- to make a legend more effective, all types of spacing within a legend must follow a hierarchy (from large to small): surrounding spacing of groups (columns/rows) of items, spacing between adjacent items, spacing between a symbol and its description, spacing between words in a description, and spacing between letters of a word;

- in effective legend design, the spacing between symbol and its description and the spacing between two adjacent lines of feature items are more important.

Although this experiment was successfully conducted, there are some limitations to declare. As the restriction of experimental environment, the pure process of visual search is difficult to record. This experiment is compensated by consideration of the time expenditure of all three sections of interaction: visual search, mouse moving and selection of feature items. In addition, experiment is designed in between-subjects survey. Although the experiences effect is avoided effectively, different groups of people testing different legends still makes the result deviation. To minimise the deviation, the age, gender and education background among groups must be similar.

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